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Motivation enhances control of positive and negative emotional distractions

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Using cognitive control to ignore distractions is essential for successfully achieving our goals. In emotionally-neutral contexts, motivation can reduce interference from irrelevant stimuli by enhancing cognitive control. However, attention is commonly biased towards emotional stimuli, making them potent distractors. Can motivation aid control of emotional distractions, and does it do so similarly for positive and negative stimuli? Here, we examined how task motivation influences control of distraction from positive, negative, and neutral scenes. Participants completed a simple perceptual task while attempting to ignore task-irrelevant images. One group received monetary reward for fast and accurate task performance; another (control) group did not. Overall, both negative (mutilation) and positive (erotic) images caused greater slowing of responses than neutral images of people, but emotional distraction was reduced with reward. Crucially, despite the different motivational directions associated with negative and positive stimuli, reward reduced negative and positive distraction equally. Our findings suggest that motivation may encourage the use of a sustained proactive control strategy that can effectively reduce the impact of emotional distraction.

Keywords: emotion, motivation, distraction, cognitive control, reward

Of the many sensory inputs competing for our attention, emotional content is prioritised (Pourtois, Schettino, & Vuilleumier, 2013). Although attending to goal-irrelevant emotional information is often adaptive, it can sometimes be detrimental (Okon-singer, Tzelgov, & Henik, 2007). From the basketball player who ignores a heckling crowd to make a free-throw, to the ex-smoker who ignores smoking-related cues, we all suppress emotional distractors to achieve our goals. To what extent can we draw on motivation when attempting to control emotional distractions? Does motivation to win the game, or improve health, increase the ability to ignore these powerful emotional cues?

Ignoring distractors is an important aspect of cognitive control (Geng, 2014). A growing literature indicates that motivation facilitates the effective use of control in emotionally-neutral contexts (Chiew & Braver, 2013), reducing interference from irrelevant distractors when rewards are offered (Botvinick & Braver, 2015; Padmala & Pessoa, 2011). But emotional stimuli are potent distractors, in part due to their biological relevance. Prioritisation of emotional stimuli may occur via separate mechanisms from classic stimulus-driven and goal-driven processes of attentional selection (Pourtois et al., 2013). Additionally, processing emotional content may use capacity-limited resources that are also recruited for cognitive control (Pessoa, 2009); if the resources required to ignore emotional distractors are partly consumed by attending to their content, they may be especially difficult to ignore. Given these differences in processing of emotional and neutral stimuli, it is unclear whether emotional distraction can be attenuated by reward at all.

Findings from two recent studies (Padmala & Pessoa, 2014; Padmala, Sirbu, & Pessoa, 2017) suggest that motivation can increase the ability to ignore emotionally-negative images. Participants judged the orientation of lines flanking a centrally-presented distractor image. Pre-cues indicated whether reward was available on each trial. Negative images slowed response times (RTs) relative to neutral images; but on reward trials, this slowing was eliminated. Further support comes from an event-related-potential study (Wei, Wang, & Ji, 2016) in which participants responded to the colour of negative and neutral words. The emotional modulation of the P3 component was eliminated on cued-incentive trials. Thus, motivation can modulate neural and behavioural responses to irrelevant emotionally-negative stimuli. Whether motivation can reduce distraction from emotionally-positive stimuli, however, remains unknown.

Biologically-relevant, high arousal, positive images can attract attention just as powerfully as negative images (Grimshaw, Kranz, Carmel, Moody, & Devue, 2017; Gupta, Hur, & Lavie, 2016; Most, Smith, Cooter, Levy, & Zald, 2007), and in some contexts they can be even more difficult to ignore. For example, using a letter-search task with centrally-presented task-irrelevant emotional images, Gupta and colleagues (2016) found that increasing the task's perceptual load eliminates distraction from negative but not positive images. Similarly, Most and colleagues (2007) report that pre-cueing the identity of a non-emotional target in a stream of rapidly-presented images reduces distraction from negative but not positive images. If motivation acts via similar control mechanisms to those elicited by these attentional manipulations, then we might expect reward to attenuate negative but not positive distraction. However, conflicting findings have been reported. Grimshaw and colleagues (2017) show that increasing distractor-frequency (also a control manipulation; Bugg & Crump, 2012) reduces distraction from both negative and positive images. Thus, whether reward affects negative and positive distraction to a similar degree may depend on the specific control mechanisms that are engaged.

Another consideration is that emotional distractors have motivational value. If reward affects control by increasing the motivational value of task-relevant targets while decreasing the relative value of distractors, it may be less effective against emotional than neutral distractors. Furthermore, the function of emotional stimuli is to prepare the body for action, guiding us to approach or withdraw (Rolls, 2005). Reward might therefore influence control of positive and negative distractors differently, due to their opposing motivational directions.

To investigate whether motivation can enhance control of emotional distraction, and if so, whether it does so similarly for positive and negative distractors, we compared the effect of reward on distraction by equally arousing positive and negative images. Participants searched for a target-letter within an array that appeared above and below a centrally-presented irrelevant image (intact on 25% of trials, scrambled on the rest). Low frequency of intact-distractors elicits relatively poor control of distraction (Bugg & Crump, 2012; Grimshaw et al., 2017). Half the participants received monetary-reward for fast and accurate performance. We expected reward to reduce distraction overall, but were specifically interested in whether reward would attenuate distraction from emotional images as effectively as it does for neutral ones. We further compared the effect of reward on distraction from negative versus positive images.

Method

Participants

Seventy-three participants (women only, to reduce within-group variance, and to allow for use of images that were carefully calibrated for valence and arousal ratings, which differ across genders) were randomly assigned to the control (*n*=36) and reward (*n*=37) groups. One outlier participant from the reward group was excluded from analysis and replaced (see Sample Size Determination), giving 36 participants per group (mean age 22.40; 18-37 years). All participants spoke fluent English, had normal or corrected-to-normal vision and reported no current treatment for depression or anxiety. Analyses were undertaken after all data were collected. The study was approved by the Victoria University of Wellington Human Ethics Committee.

Stimuli and Apparatus

Participants ran in groups of one to four in a dimly-lit room in separate booths. The experiment was run using E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA) on Dell-Precision-T1700 personal-computers with 24” monitors at 1920x1080-pixel resolution and a 120Hz refresh rate. A chin-rest maintained a viewing distance of 57cm.

Twelve images for each category[1] (negative, neutral, positive) were drawn from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). The positive (erotic couples) and negative (mutilation) images were matched on arousal using normative ratings from women (arousal: positive $M = 6.31$, negative $M = 6.53$; valence: negative $M = 1.64$, positive $M = 6.23$), to avoid confounding valence differences with arousal. The neutral images contained people and thus had biological and social relevance (like emotional images), but lacked emotional valence ($M = 5.01$) and arousal ($M = 3.07$). To create scrambles, images were divided into 36x36 segments that were randomly recombined in PhotoScape-v3.7. Scrambled images thus had the same lower level visual properties as intact distractors; comparing performance on intact vs. scrambled trials therefore estimates distraction due to the images’ meaning. All images were matched for luminance and contrast using the SHINE-MATLAB-toolbox (Willenbockel et al., 2010).

Design and Procedure

Figure 1A illustrates the distraction task. Each trial began with a central white fixation cross (between 417-833 ms) on a black background, followed by a 200 ms target display, which comprised a centrally-presented colour image (11° width x 8.26° height; intact on 25% of trials, scrambled on 75%), flanked by six white letters (0.86° x 0.92°); three located 0.75° above and three 0.75° below the image's horizontal edge. Five of the letters were 'O's and the target was 'K' or 'N'. Participants were instructed to ignore the images and respond quickly and accurately to indicate whether 'K' or 'N' was present, using keys '1' and '2' (counterbalanced across participants) on the number-pad. Participants responded during an 1800 ms response-window from stimulus-offset (anticipatory responses <200 ms were excluded; <0.01% of trials). Failure to respond was recorded as an error. A 600 ms blank screen followed the response, followed by visual feedback (100 ms): 'correct', 'incorrect', or 'please respond faster' (if no response was made). A random inter-trial-interval ranged between 207-623 ms. Target letter and location were counterbalanced across trials and trial order was randomised.

Participants completed 24 practice trials (six intact, 18 scrambled) and a baseline-block of 48 trials (12 intact, 36 scrambled); these blocks contained neutral images, different from those presented on experimental trials. The experiment was split into two halves (super-blocks) of 192 trials (counterbalanced). One super-block contained negative and neutral distractors; the other contained positive and neutral distractors (separated by a three-minute break to limit valence carry-over effects). Each super-block comprised two emotional and two neutral blocks (separated by self-timed breaks), presented in ABBA (counterbalanced) order. Within a block (48 trials; 12 intact, 36 scrambled), all images were *either* negative, neutral, or positive, mixed with scrambles created from the same images. Each intact image was presented once in a block, although images were repeated (emotional images twice; neutral images four times) across the experiment to increase trial numbers. This yielded four possible block orders, counterbalanced across participants.

Reward Condition.

After the baseline-block, participants were informed about the potential to earn one point per-trial if they were correct and faster than their median RT from the baseline-block. Success was indicated by a pleasant sound during the 600 ms post-response-window. Winning points led to achieving 'levels'; reaching a new level increased earnings by $2.50. Participants began on level 1 ($10). Level 2 required 91 points ($12.50). Ninety-one additional points were needed to ascend to each new level, up to level 5 ($20). During each break, point total and current level appeared above an animated coin display, with mean RT and percent accuracy for the preceding block. Participants were reminded to be fast and accurate. A warning was provided if accuracy fell below 95%. Participants earned between $15 and $20 (*M*=$16.22).

Control Condition.

Control participants completed the task as above, but were offered $15, unconnected to performance. They received visual but not auditory feedback. During the breaks instead of performance feedback and the coin animation; they saw 'please wait…', and instructions to take a break.

Sample Size Determination

To determine the sample size needed to detect an effect of reward on emotional distraction, we used the effect size (d_s = .84) from Grimshaw et al. (2017), using distractor-frequency (25% vs. 75%) as a proxy for the potential effect of reward on emotional distraction (RT-intact – RT-scrambled, collapsed across positive and negative). At 90% power (α=.05), this yielded 26 participants per group. We rounded up to 36 participants per group for counterbalancing purposes. One participant from the reward group was excluded from analyses and replaced because she showed 466 ms of negative distraction, >4 SDs above the mean for negative distraction in the reward condition.

Results

RTs and accuracy for neutral blocks did not differ across the two super-blocks (intact and scrambled conditions; *p*'s >.260), so we collapsed the neutral blocks in analyses. Mean correct RTs and accuracy for each condition, and comparisons between intact and scrambled conditions, are presented in Table 1. Degrees of freedom are adjusted for heterogeneity of variance (Greenhouse-Geisser) where necessary. Effect sizes are Hedge's *g* for between-subject comparisons, and Cohen's d_{rm} for within-subject comparisons (Lakens, 2013). Confidence-intervals are 95%.

RTs

See Figure 1B for mean distraction in each condition. Correct RTs were analysed in a 2 (reward: reward, control) x 3 (distractor-valence: negative, neutral, positive) x 2 (distractor-type: intact, scrambled) analysis of variance (ANOVA), with reward as the between-subjects factor and the other factors within-subjects.

Main effects of distractor-valence $F(1.85, 129.20) = 11.01$, $p <.001$, $\eta_p^2 = .14$ and distractor-type $F(1, 70) = 122.36$, $p <.001$, $\eta_p^2 = .64$, were qualified by a distractor-valence x distractor-type interaction $F(2, 140) = 30.94$, $p <.001$, $\eta_p^2 = .31$. Comparing distraction (intact-RT– scrambled-RT) showed that the interaction was due to greater negative and positive than neutral distraction: negative distraction (M = 75 ms, SD = 70 ms) was greater than neutral distraction (M = 26 ms, SD = 22 ms), $t(71) = 6.73$, $p <.001$, $d_{rm} = .80$, CI [35, 63]; and positive distraction (*M* = 65 ms, *SD* = 64 ms) was greater than neutral distraction, $t(71) = 5.63$, p <.001, d_{rm} = .73 CI [25, 53]. Positive and negative distraction did not significantly differ, $t(71) = 1.68$, p =.098, d_{rm} = .15, CI [-2, 22].

A main effect of reward confirmed that the reward group (*M* = 571 ms, *SD* = 89 ms) was faster than the control group (*M* = 654 ms, *SD* = 126 ms), $F(1, 70) = 10.40$, p =.002, η_p^2 = .13. The predicted reward x distractor-type interaction, $F(1, 70) = 10.14$, p =.002, η_p^2 = .13, was followed-up by comparing distraction between the groups. The reward group was 32 ms less distracted (*M* = 39 ms, *SD* = 34 ms) than the control group (*M* = 71 ms, *SD* = 49 ms), $t(70) = 3.18$, p =.002, g = .74, CI [12, 52].

A reward x distractor-type x distractor-valence interaction[2], $F(2, 140) = 5.20$, p = .007, η_p^2 = .07, was driven by a reduction in emotional distraction with reward: negative distraction was 42 ms lower in the reward group (*M* = 54 ms, *SD* = 60 ms) compared to the control group (*M* = 96 ms, *SD* = 73 ms), $t(70) = 2.70$, p =.009, g = .63, CI [11, 74]. Positive distraction was 46 ms lower in the reward group (*M* = 88 ms, *SD* = 70 ms) compared to the control group (*M* = 42, *SD* = 48 ms), $t(62.11) = 3.24$, p =.002, g = .76, CI [18, 74]. In contrast, for neutral distraction there was no significant difference between the reward (*M* = 22 ms, *SD* = 18 ms) and control (*M* = 30 ms, *SD* = 25 ms) groups, $t(70) = 1.46$, p =.150, g = .34, CI [-3, 18]. Emotional distraction is clearly reduced by reward.

To directly test our question of whether positive and negative distraction were affected similarly by reward, we ran an ANOVA with the same factors but excluded neutral blocks. The reward x distractor-type x distractor-valence interaction was not close to significant $F(1, 70) = 0.07$, p =.788, η_p^2 = .001. An equivalence test (Lakens, 2017), using the smallest effect size we could detect at 90% power (d_z = .39) as the lower and upper bounds, indicated that the size ($d_z = 0.03$) of the group difference did not differ between positive and negative conditions, $t(35) = 2.14$, $p = .020$; the effect of reward was not influenced by distractor-valence.

No other effects reached significance.

Accuracy

Accuracy (proportion correct) was similarly analysed in a 2x3x2 ANOVA. A main effect of reward showed that the reward group ($M = .899$, $SD = .061$) was less accurate than the control group ($M = .935$, $SD = .039$), $F(1, 70) = 8.82$ $p = .004$, $\eta_p^2 = .11$, indicating a speed-accuracy-trade-off (see Inverse-efficiency, below). Main effects of distractor-valence, $F(2, 140) = 10.74$, $p < .001$, $\eta_p^2 = .13$, and distractor-type, $F(1, 70) = 43.17$, $p < .001$, $\eta_p^2 = .38$, were qualified by a marginal distractor-valence x distractor-type interaction, $F(2, 140) = 2.51$, $p = .085$, $\eta_p^2 = .04$. Follow-up tests revealed that negative distraction was marginally higher than neutral distraction, $t(71) = 1.79$, $p = .078$, $d_{rm} = .30$, CI [-.002, .037]. Positive distraction was significantly higher than neutral distraction, $t(71) = 2.17$, $p = .033$, $d_{rm} = .36$, CI [.002, .041]. Positive and negative distraction did not differ from each other, $t(71) = 0.39$, $p = .700$, $d_{rm} = .06$ CI [-.025, .017]. RT and accuracy results converge to reflect greater emotional than neutral distraction. No other effects reached significance.

Inverse-efficiency

To ensure that a speed-accuracy-trade-off did not account for the effect of reward on emotional distraction, we conducted an ANOVA on inverse-efficiency scores (adjusting RTs for accuracy: [RT/proportion correct], see Bruyer & Brysbaert, 2011). Consistent with the RT analysis, the distractor-type x reward interaction, $F(1, 70) = 6.05$, $p = .016$, $\eta_p^2 = .08$; and distractor-valence x distractor-type x reward interaction, $F(2, 140) = 4.75$, $p = .010$, $\eta_p^2 = .06$, remained significant. Negative distraction, $t(70) = 2.29$, $p = .025$, $g = .53$, CI [9, 131], and positive distraction, $t(70) = 2.62$, $p = .011$, $g = .61$, CI [14, 106], were both attenuated by reward, whereas neutral distraction did not differ between groups, $t(70) = 0.06$, $p = .951$, $g = .01$, CI [-17, 18]. All other significant effects mirrored those in the RT analyses.

Discussion

We find that emotional images are more distracting than neutral ones, but that emotional distraction is attenuated by the availability of performance-contingent reward. Only two previous studies have addressed the effect of reward on suppression of negative images (Padmala & Pessoa, 2014; Padmala et al., 2017). We replicate and extend these findings, showing that despite the opposing motivational directions associated with positive and negative stimuli (approach and withdrawal), motivation is similarly effective in enhancing control of both positive and negative distractions.

The benefit of reward for both negative and positive distraction parallels the effect of increased distractor frequency (Grimshaw et al., 2017). According to the Dual Mechanisms of Control Framework (Braver, Gray, & Burgess, 2007), both expectations (manipulated by distractor-frequency), and motivation (manipulated by reward), act in a top-down manner to shift control from a reactive strategy (triggered when distraction occurs) to a proactive one (using anticipatory control to prevent distraction before it occurs). The influence of reward on proactive control has been repeatedly demonstrated in emotionally-neutral contexts (see Botvinick & Braver, 2015). Here, we show that it might be possible to extend this model to contexts in which distractors are negative and positive stimuli. Surprisingly, reward did not attenuate neutral distraction. Neutral distraction was relatively low, suggesting a possible floor-effect, or an effect too small to be detected in this study.

Our finding contrasts reports of other attentional manipulations that attenuate negative but not positive distraction. Notably, these studies manipulated perceptual load (Gupta et al., 2016) and attentional settings (Most et al., 2007) to affect control. These discrepancies logically suggest that multiple control mechanisms may be used to control emotional distractions, depending on the factor that elicits control (e.g., perceptual load vs. reward). We note that *proactive* and *reactive* are collective terms (referring to timing) that each comprise multiple possible mechanisms. One possibility is that other (non-reward) manipulations affect reactive control, which could be sensitive to emotional valence. Alternatively, other (non-reward) control manipulations could affect a different proactive mechanism than motivation does. Further studies to directly compare the effects of different manipulations will be useful for identifying the conditions under which different control mechanisms are engaged. Online measures of control (e.g., pupillometry or electrophysiology; e.g., Chiew & Braver, 2013) will provide insight into the time-course of control elicited by different manipulations.

The present findings suggest a number of future extensions. First, blocking distractors by valence enabled us to maximise emotional distraction while minimizing carry-over effects, so as to demonstrate the effect of reward on positive and negative distraction separately. Blocking allows participants to predict a distractor's valence. To the extent that expectations influence the mechanisms used to control emotional distraction, it is possible that reward might be equally effective for controlling distractions with predictable valence, but not distractors whose valence is unpredictable. Designs in which distractor-valence is unpredictable will be useful in examining how expectations affect control of distraction. Second, our use of between-subjects, blocked incentive (intended to maximise the impact of reward), resulted in a strong test of whether motivation can act globally to affect sustained control of negative and positive distractions. Our manipulation contrasts with that of Padmala and colleagues (2014; 2017), who manipulated reward within-subjects, via pre-trial cues. Their findings therefore reflect a dynamic, trial-by-trial shift in control of negative distraction. Future research should address whether these dynamic shifts are possible when controlling positive distractions. Lastly, we focussed on the distracting effect of specific categories of emotional distractors (erotic couples, mutilations); and did so only in women. The present findings invite extension to different categories of images, and to men and women.

We often encounter situations in which positive and negative cues compete with more mundane, but goal-relevant stimuli. Cognitive control mechanisms are necessary in these situations to negotiate an optimal outcome. Our study shows that motivation is one way of enhancing control over both negative and positive distractions. The relationship between emotion, motivation, and cognitive control is complex (Pessoa, 2009), and research examining their interplay is in its infancy. Further exploration of their interactions will provide richer understanding of the conditions under which current goals are successfully achieved.

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Footnotes

[1]IAPS images: Neutral: 2026, 2102, 2221, 2305, 2393, 2397, 2411, 2512, 2593, 2595, 2745.1, 2840. Negative: 3015, 3030, 3059, 3103, 3131, 3140, 3150, 3195, 3550.1, 9253, 9405, 9420. Positive: 4658, 4659, 4660, 4668, 4680, 4690, 4693, 4694, 4695, 4697, 4698, 4800.

[2]With the outlier participant included, this reward x distractor-type x distractor-valence interaction becomes non-significant, $F(2, 142) = 2.31$, $p = .103$, $\eta_p^2 = .03$; the outlier disproportionately influences the variance of negative distraction in the reward group (included $M = 65$ ms, $SD = 90$ ms; excluded $M = 54$ ms, $SD = 60$ ms) reducing the effect of reward on negative distraction, $t(71) = 1.63$, $p = .107$, $d = .38$, CI [-7, 70]. Outlier inclusion did not influence the significance of any other findings.

Table 1. Comparisons of mean correct RTs (ms) and accuracy (proportion correct) for scrambled versus intact images (distraction), for each distractor-valence condition, separately for control and reward groups.

Valence Block	Scrambled Trials	Intact Trials	Distraction	d_{rm}	95% CI Low	95% CI Upper
			Response Times			
Control Group						
Negative	614 (116)	710 (155)	96***(72)	.61	72	121
Neutral	618 (120)	648 (131)	30***(25)	.21	21	38
Positive	624 (117)	712 (156)	88***(70)	.54	64	111
Reward Group						
Negative	550 (80)	603 (119)	53**(60)	.42	33	74
Neutral	551 (79)	573 (85)	22***(18)	.26	16	28
Positive	554 (83)	596 (113)	42***(48)	.34	26	58
			Proportion Correct			
Control Group						
Negative	.950 (.041)	.902 (.080)	.048***(.069)	.70	.025	.071
Neutral	.958 (.031)	.942 (.048)	.016 (.039)	.35	.002	.028
Positive	.949 (.045)	.905 (.072)	.044** (.075)	.72	.019	.070
Reward Group						
Negative	.899 (.067)	.877 (.089)	.022 (.072)	.27	-.002	.047
Neutral	.919 (.059)	.898 (.069)	.021** (.044)	.32	.006	.036
Positive	.915 (.066)	.881 (.085)	.034** (.070)	.44	.010	.058

Notes: Distraction is calculated as: [RT intact – RT scrambled] and [proportion-correct scrambled – proportion-correct intact]. SDs are in brackets. Effect sizes are Cohen's d_{rm} from paired comparisons of intact and scrambled trials within conditions, and asterisks indicate whether the intact – scrambled difference is significant in that condition. *$p < .05$, **$p < .01$, ***$p < .001$. 95% confidence intervals surround the distraction scores, in ms and proportion correct. $n = 36$ per group.

Figure 1. (A) Schematic trial sequence. The displays are enlarged to enhance the central portion of the screen and so are not to scale. (B) Mean distraction in ms (RT intact – RT scrambled) is shown for the control and reward groups for each valence condition. Error bars represent ±1 95% confidence intervals.